OPTIMIZATION OF TOOL LIFE IN MILLING

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ABSTRACT

This paper discuss of the Optimization of Tool Life in Milling. The objective of the paper is to obtain an optimal setting of turning process parameters –cutting speed, feed and depth of cut, which may result in optimizing tool life of TiN coated carbide inserts while milling aluminium 6061. Data is collected from FANUC Robodrill CNC milling machines were run by 15 samples of experiments. A dimensional-accuracy model for the end milling of aluminum alloys under dry conditions is presented. To build the quadratic model and minimize the number of experiments for the design parameters, response surface methodology (RSM) with a Box-Behnkin method is used to design the table in MINITAB packages. The inputs of the model consist of feed, cutting speed and depth of cut while the output from the model is tool life and tool wear was measured using Image Analyzer microscope.The model is validated through a comparison of the experimental values with their predicted counterparts. A good agreement is found where from the RSM approaches which reliable to be use in tool wear prediction. The direct and interaction effect of the machining parameter with tool wear were analyzed and plotted, which helped to select process parameter in order to reduce tool wear which ensures quality of milling. It is shown that the tool wear in end milling decreases with the increase in feed, radial depths of cut and cutting. From the experiment it is found that the effect of axial depth of cut on tool life is not so significant. The speed effect is dominant followed by the feed and the axial depth of cut. For end-milling of aluminium alloy 6061, the optimum condition that is required to maximize the coated carbide tool life are as follow: cutting speed of 180m/min, federate of 0.2 mm/rev, axial depth of 1.5 mm.

ABSTRAK

Kertas kajian ini membincangkan tentang mengoptimum kehidupan mata alat dalam proses pengilingan. Objektif kertas kerja ini adalah untuk mendapatkan gubahan parameter yang optimal oleh mesin penggilingan-kelajuan pemotongan,nilai suapan dan kedalaman pemotongan, yang dimana akan member kesan dalam mengoptimum sisipan mata alat TiN coated carbide semasa memesin aluminium 6061. Data di kumpul dari mesin menggiling CNC FANUC Robodrll dimana dijalankan menggunakan 15 sampel eksperiment. Model dimensi ketepatan untuk proses pengiligan hujung untuk aluminium aloi dibawah kondisi kering digunakan. Untuk membina model kuadratik dan mengurangkan jumlah eksperimen untuk rekacipta parameter, response surface methodology (RSM) dengan cara Box-Behkin digunakan untuk mereka-cipta jadual di dalam MINITAB. Penghasilan model terdiri daripada nilai suapan, kelajuan pemotongan dan kedalaman memotong dimana outputnya dari model ini adalah kehidupan mata alat dan kehausan mata alat di ambil dengan menggunakan Image Analyzer mikroskop. Kesan laluan dan interaksi parameter pemesinan dan kehausan mata alat di analisis dan di plot graf dengan, dimana ianya membantu untuk memilih proses parameter dengan tujuan untuk menurangkan kehausan mata alat dan memastikan kualiti penggiligan. Itu ditunjukan yang mana kehidupan mata alat dalam proses menggiling hujung rendah dengan menambahkan nilai pada suapan, jumlah kedalaman pemotongan dan kelajuan pemotongan. Ini juga didapati bahawa jumlah kedalaman pemotongan mempunyai signifikan yang paling banyak mempengaruhi kehausan mata alat didalam proses pemotongan hujung terhadap aluminium aloi.

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LIST OF SYMBOLS

f	Feed Rate, mm/rev
d	Depth of Cut, mm
V_C	Cutting Speed, m/min
L	Cutting Length, mm
D	Workpiece Diameter, mm
N	Spindle Speed, rpm
Vc	Crater Wear, mm
Vb	Flank wear, mm
μ	Mean

LIST OF ABBREVIATIONS

DOE	Design of Experiment
CNC	Computer Numerical Control
TiN	Titanium Nitride
CVD	Chemical vapor deposition
PVD	Physical vapor deposition
SEM	Scanning Electron Microscope
PSO	Particle Swarm Optimization
AISI	American Iron and Steel Institute
ISO	International Organization for Standardization

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The development of miniaturised technologies has become a global phenomenon that continues to make an impact across a broad range of applications that encompasses many diverse fields and industries. One of the technologies used to create these miniaturized components is milling. In order to optimise the economic performance of metal cutting operation, efficient quantitative and predictive models that establish the relationship between a big of independent parameters and output variables are required for the wide spectrum of manufacturing processes, cutting tools and engineering materials currently used in industry.

Furthermore, it has been observed that the improvement in the output variables such as tool life, cutting forces and surface roughness through the optimisation of input parameters such as feed rate, cutting speed and depth of cut may result in significant economical performance of machining operations. One of these output variables that may have either direct or indirect indications on the performance of other variables such as tool wear rate, machined surface characteristics and machining cost is cutting force.

1.2 PROBLEM STATEMENT

Optimum tool life is great concern in manufacturing environments where, economy of machining operation plays a key role in competitiveness in the market. The milling process compare to the other metal machining process is quite slow thus having a low production rate. Although NC machines function is to reduce lead times considerably, the machining time is almost the same as conventional machining where machining parameters are selected from machining databases or handbooks.

Milling process can be used on the non-ferrous and ferrous material. Inaccuracy of cutting tool contribute to poor surface finish, tool damage, chatter, dimensional accuracy and many other problems that contribute to low productivity and much time to be wasted. (Kalpakjian and Schmid 2003).

One of the popular cutting tools that are used is coated carbide inserts. This study helps to improve the performance of milling process by using coated carbide tool as a cutter for the optimum performance using. This project also can helps mass production machining in our industry (S. Krar et al 1994).

1.3 PROJECT OBJECTIVE

The objective of this project is to:

(i) Investigate and predict the type of tool wear in end milling using CNC milling machine of aluminum alloy 6061.
(ii) Determine the optimum parameters to increased tool life for milling to maximize the production rate and minimum production cost in industry.

1.4 PROJECT SCOPE

The scope of project covered study and analysis about tool life and the project consists of this below:

(i) The research is focus on milling of Aluminum 6061 in end milling under dry condition.

(ii) Machining parameters considered are depth of cut, federate, and cutting speed. Constant feed rate and depth of cut were set based on literature.

(iii) The cutting speed varied range from 100,140 and 180 m/min. Feed range from 0.1, 0.15, 0.2 mm/tooth and axial depth range is 1, 1.5,2 mm.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Tool life is an important aspect commonly considered in evaluating the performance of a machining process. In addition, tool life estimates and the corresponding economic analysis are among the most important topics in process planning and machining optimization. The coefficients are also a function of tool wear, which typically results in increased cutting forces as the tool wears. The need for measurement of all cutting force component arises from many factors, but probably the most important is need correlation with the progress of tool wear. It is well known that during the machining, the cutting parameters such as cutting speed, feed rate and depth of cut often present a deviation from the calculated values. Furthermore, it has been observed that the improvement in the output variables may result in a significant economical performance of machining operations. The aspect need to be considered for the tool life is cutting force on the workpiece and the temperature during machining that are subjected by the cutter tools and tool wear can be measured by using microscope (Prickett, and Johns, 1999).

2.2 MILLING MACHINE

Milling is the process of machining flat, curved or irregular surface by feeding the workpiece against a rotating cutter containing a number of cutting edges. Milling process consists of a motor driven spindle, which mounts and revolves the milling cutter and a reciprocating adjustable worktable, which mounts and feeds the workpiece.

Milling machines are basically classified as vertical or horizontal. These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type. Most milling machine have self-contained electric drive motors, coolant systems, variable speeds and power-operated table feeds.

Milling machine is a machine tool that cuts metal with multiple-tooth cutting tool called a milling cutter. The workpiece is fastened to the milling machine table and is fed against the revolving milling cutter. The milling cutter can have cutting teeth on the periphery or side or both. (S. Krar et al, 1994).

Milling machine can be classified into three main headings:

i. General Purpose machines – these are mainly the column and knee type (horizontal and vertical machines).
ii. High Production types with fixed beds – (horizontal types)
iii. Special purpose machines such as a duplicating, profiling, rise and fall, rotary table planetary and double end types.

Milling attachments can also be fitted to other machine tools including lathes planning machines and drill bench presses can be used with milling cutters. Milling machine is one of the most versatile conventional machine tools with a wide range of metal cutting capability. Many complicated operations such as indexing, gang milling and straddle milling can be carried out on a milling machine (Kalpakjian and Schmid 2003).

2.3 CLASSIFICATION OF MILLING

2.3.1 Slab Milling

In slab milling, also called peripheral milling, the axis of cutter rotation is parallel on the workpiece surface to be machined .Cutter for slab milling may have straight or helical teeth resulting in respectively, orthogonal or oblique cutting action. The helical tooth on the cutter is preferred over straight teeth because the load on the tooth is lower, thus smoother operation and reducing tool force and chatter (S. Krar et al, 1994).

2.3.2 Face Milling

In face milling, the cutter is mounted on a spindle having an axis of rotation perpendicular to the workpiece surface (Kalpakjian and Schmid 2003). The milled surface results from the action of cutting edges located on the periphery and face of the cutter.

2.2.3 End Milling

Flat surface as well as various profiles can be produced by end milling. The cutter in end milling has either straight or tapered shanks for smaller and larger cutter sizes respectively. The cutter usually rotates on an axis perpendicular to the workpiece, although it can be tilted to machine-tapered surface (Kalpakjian and Schmid 2003).

2.4 MECHANISM OF MILLING

2.4.1 Up Milling (conventional milling)

The safe way to machine a piece of metal using a horizontal miller is to feed the metal into the cutter, against its rotation. This is called up-milling and it’s the technique used in school workshops. The metal must be held very firmly in a large machine vice to ensure it is extremely tight. In up milling the maximum chip thickness is at the end of the cut. The advantages of using up milling are the cutting process is smooth, provide that the cutter teeth are sharp. However they may be a tendency for the tool to chatter and the workpiece has to pull upward (Kalpakjian and Schmid 2003).

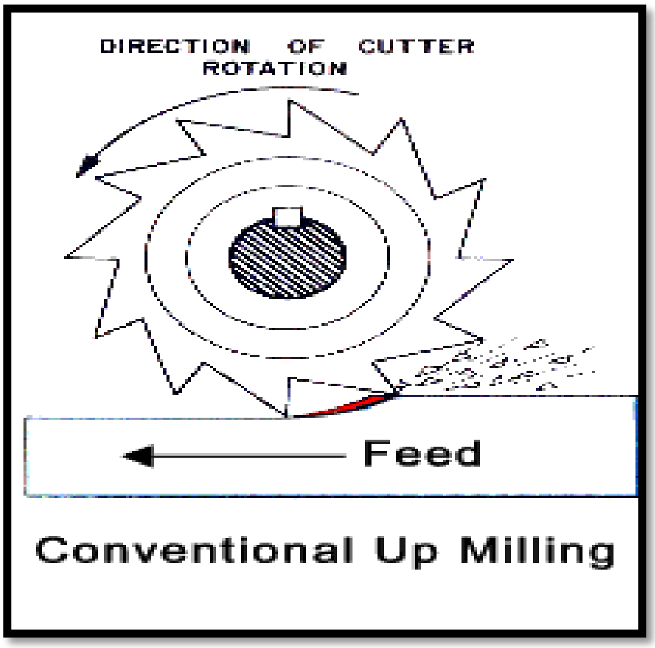

Figure 2.1: Up Milling

Source: Kalpakjian and Schmid 2003

2.4.2 Down Milling (climb milling)

Down milling is also referred to as climb milling. The direction of cutter rotation is same as the feed motion. For example, if the cutter rotates counter clockwise, the workpiece is fed to the right in down milling. The advantage is that the downward components of the cutting force hold the workpiece in place. However it is not suitable for the machining of a workpiece having a surface scale such as hot worked metals, forgings and casting. The scale is hard and abrasive and can cause excessive wear and damage to the cutter teeth, shortening tool (Kalpakjian and Schmid 2003).

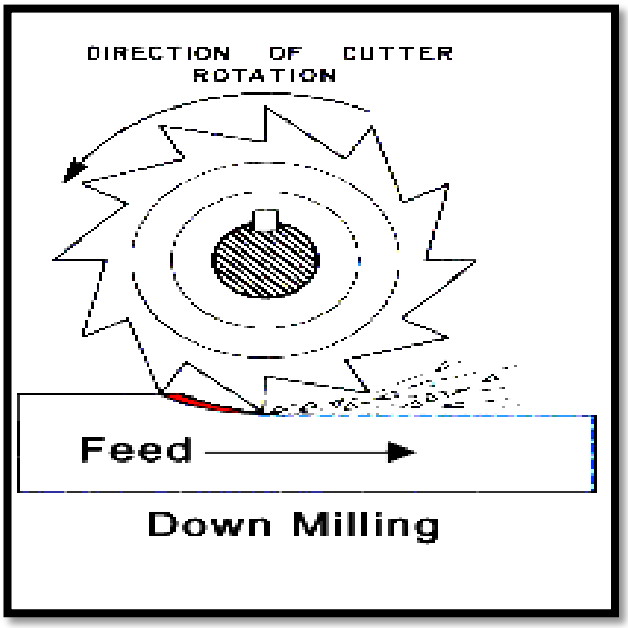

Figure 2.2: Down Milling

Source: Kalpakjian and Schmid 2003

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2.5 TYPE OF MILLING MACHINE

2.5.1 Vertical Milling Machine

In the vertical mill the spindle axis is vertically oriented. Milling cutters are held in the spindle and rotate on its axis. The spindle can generally be extended (or the table can be raised/lowered, giving the same effect), allowing plunge cuts and drilling. There are two subcategories of vertical mills: the bedmill and the turret mill. Turret mills, are generally smaller than bedmills, and are considered by some to be more versatile. In a turret mill the spindle remains stationary during cutting operations and the table is moved both perpendicular to and parallel to the spindle axis to accomplish cutting. In the bedmill, however, the table moves only perpendicular to the spindle's axis, while the spindle itself moves parallel to its own axis. Also of note is a lighter machine, called a mill-drill. It is quite popular with hobbyists, due to its small size and lower price. These are frequently of lower quality than other types of machines (Kalpakjian and Schmid 2003).

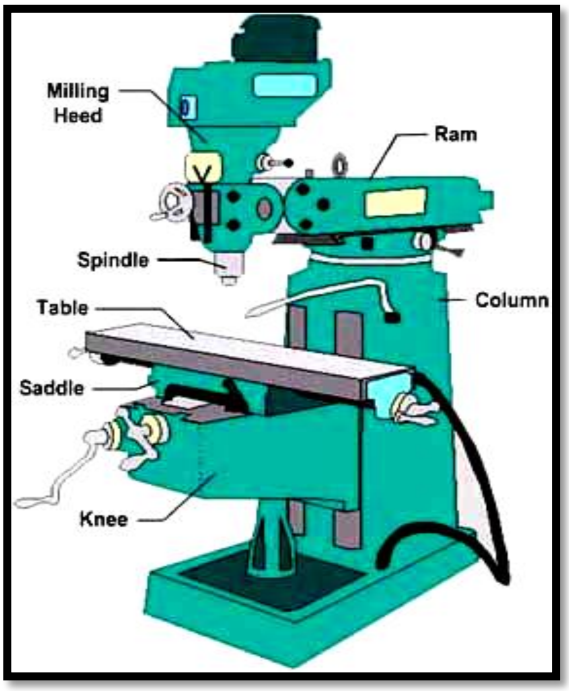

Figure 2.3: Vertical Milling Machine

Source: Krar, et al 1994

2.5.2 Horizontal Milling Machines

A horizontal mill has the same sort of x–y table, but the cutters are mounted on a horizontal arbor across the table. A majority of horizontal mills also feature a +15/-15 degree rotary table that allows milling at shallow angles. While endmills and the other types of tools available to a vertical mill may be used in a horizontal mill, their real advantage lies in arbor-mounted cutters, called side and face mills, which have a cross section rather like a circular saw, but are generally wider and smaller in diameter. Because the cutters have good support from the arbor, quite heavy cuts can be taken, enabling rapid material removal rates. Several cutters may be ganged together on the arbor to mill a complex shape of slots and planes. Special cutters can also cut grooves, bevels, radii, or indeed any section desired. These specialty cutters tend to be expensive. Simplex mills have one spindle, and duplex mills have two. It is also easier to cut gears on a horizontal mill. (S. Krar, et al 1994).

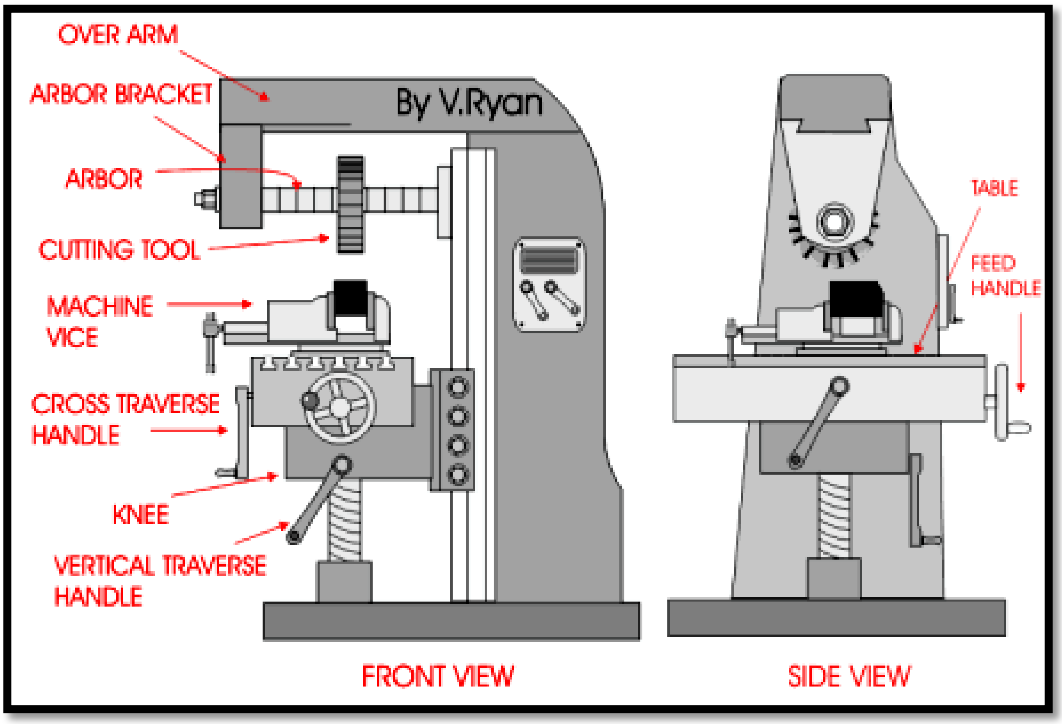

Figure 2.4: Example of horizontal milling machine

Source: Armarego et al, 1999

2.5.3 Computerized Numerical Control Machine (CNC machine)

CNC machine is a Computerized Numerical Control machine that the tool is controlled by a computer and is programmed with a machine code system that enables it to be operated with minimal supervision and with a great deal of repeatability**. CNC** mills can perform the functions of drilling and often turning. **CNC** mills are classified according to the number of axes that they posses. Axes are labelled as x and y for horizontal movement, and z for vertical movement. The same principles used in operating a manual machine are used in programming a **CNC** machine The main difference is instead of cranking handles to position a slide to a certain point, the dimension is stored in the memory of the machine control once. The control will then move the machine to these positions each time the program is run. **CNC** machine also economic to use for big size capacity for production and for special case **CNC** can be use (Armarego et al, 1999).

Figure 2.5: CNC milling machine

2.6 TOOL

In the context of machining, a cutting tool (or cutter) is any tool that is used to remove material from the workpiece by means of shear deformation. Cutting tools must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal-cutting process. Also, the tool must have a specific geometry, with clearance angles designed so that the cutting edge can contact the workpiece without the rest of the tool dragging on the workpiece surface. The cutter are generally made from high speed steel (HSS) and coated carbide which means they will cut through metals such as mild steel and aluminium. There are many variables, opinions and lore to consider before selects a milling cutter (S. Krar, et al 1994).

2.6.1 Tool Material

Various cutting-tool materials with a wide range of mechanical, physical, and chemical properties have been developed over the years. The desirable tool-material characteristics are chosen based on the criteria below:

(i) Hardness and strength are important with regard to the hardness and strength of the workpiece material to be machined.
(ii) Impact strength is important in making interrupted cuts in machining, such as milling.
(iii) Melting temperature of the tool material is important versus the temperatures developed in the cutting zone.
(iv) The physical properties of thermal conductivity and coefficient of thermal expansion are important in determining the resistance of the tool materials to thermal fatigue and shock.

Tool materials generally are divided into the following categories, including:

(i) High-speed steels
(ii) Cast-cobalt alloys
(iii) Carbides
(iv) Coated tools
(v) Alumina-based ceramics
(vi) Cubic boron nitride